Unsteady pressure field analysis in different configurations of decelerated swirling flow with 90° sharp heel elbow

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Abstract. The wide range operation of Francis turbines is a challenging requirement. Often, leads to development of strong unsteady phenomena (e.g., vortex rope) associated with strong pressure pulsations. Moreover, these phenomena interact with other components from the hydraulic circuit and leads to pressure pulsations that are propagated in the entire hydraulic circuit. In this paper, a swirl generator is used to study the swirling flow interaction and unsteady behaviour when a sharp heel elbow (HE90) is mounted downstream to the cone. Several swirling flow configurations are obtained by controlling the rotor speed of the swirl generator apparatus with a magnetorheological brake (MRB). The plunging and rotating components are studied and the conclusions are underlined.

1. Introduction

The operating conditions of hydraulic turbines has dramatically changed due to the requirements in the energy market [1]. The flexible operation of the hydraulic turbines consists in wide range of discharge and head values. The flow instabilities in the discharge cone of hydraulic turbine with fixed blades (e.g. Francis, propeller) are developed during off-design conditions due to the residual swirl. Schilling et al. [2] have investigated a rotor with adjustable blades installed downstream to the runner of a pump-turbine to diminish unsteady phenomena and to improve its cavitational behaviour. Resiga et al. [3] have numerically evaluated the behaviour of a tandem solution with low-pressure runner (LPR) with variable speed installed downstream to high-pressure runner (HPR) of a Francis turbine. The residual swirling flow delivered by HPR at off-design conditions is modified by the LPR controlling its speed. In this way, the swirling flow configuration at the inlet of the draft tube is controlled diminishing the unsteady phenomena and improving the pressure recovery along the draft tube cone. The speed control of this LPR may be done by a magneto-rheological brake (MRB) [4].

This paper aims to investigate the dynamic behaviour of the self-induced unsteadiness developed in different swirling flow configurations obtained with MRB. Several swirling flow configurations are generated at the inlet of the cone slowing down the rotor speed of a swirl generator apparatus with a magneto-rheological brake (MRB). The test rig setup together with the geometrical configuration of the test section are presented in Section 2. Section 3 includes the experimental data recorded and results on five levels (four levels selected along the cone and one level located upstream, see Figure 1) of the test section together with 90° heel elbow. The decomposed power spectra of the equivalent amplitude in terms of the Strouhal number of the unsteady pressure signals acquired at the cone wall for different